DOCUMENT RESUME

ED 297 745 IR 052 417

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TITLE Private Copying, Appropriability, and Optimal Copying Royalties.
INSTITUTION Rand Corp., Santa Monica, Calif.
SPONS AGENCY National Science Foundation, Washington, D.C.
REPORT NO ISBN-0-8330-0828-5; RAND/R-3546-NSF
PUB DATE Oct 87
GRANT IST-8415297
NOTE 43p.
AVAILABLE FROM The RAND Corporation, Publications Department, 1700 Main St., Santa Monica, CA 90406-2138 ($4.00 for 1-24 copies, 25 copies or more receive a 25% discount).
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Case Studies; *Consumer Protection; *Copyrights; Costs; *Intellectual Property; Legislation; Mathematical Models; *Policy; Producer Services; *Reprography; Technological Advancement
IDENTIFIERS *Profits; *Royalties

ABSTRACT

This report analyzes the economic effects of the reproduction of intellectual property, i.e., books, journals, computer software, and audiovisual materials. A general economic model is presented in which direct appropriability (the marginal cost of copying is constant) and indirect appropriability (the marginal cost of copying is rising) appear as particular outcomes arising from particular assumptions regarding the marginal costs of copying. The model focuses on two aspects of private copying: the extent to which originals and copies are substitutes for consumers, and the technology for making copies from originals. Variants of the basic model, each of which is defined by a characterization of copying technology and substitutability, are examined in three cases. The model is then applied to the problem of determining the royalties to be charged for making copies. The analysis in this report indicates that the effects of private copying differ considerably depending on the assumptions regarding the substitutability between originals and copies and the relative costs of producing copies and originals, which has important implications for the appropriate public policy to pursue regarding such copying. (21 references) (CGD)

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Private Copying, Appropriability, and Optimal Copying Royalties

Stanley M. Besen, Sheila Nataraj Kirby

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The work described in this report was supported by the National Science Foundation under Grant IST-8415297.

ISBN: 0-8330-0828-5

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Published by The RAND Corporation
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90406-2138

R-3546-NSF

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Stanley M. Besen, Sheila Nataraj Kirby

October 1987

Supported by the
National Science Foundation

RAND

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PREFACE

This report was supported by a grant from the Information Impact Program of the National Science Foundation's Division of Information Science and Technology. It extends the analysis previously reported in S. M. Besen, *Private Copying, Reproduction Costs, and the Supply of Intellectual Property*, The RAND Corporation, N-2207-NSF, December 1984, by developing a more general economic model of private copying. The analysis focuses on the nature of private copying costs and the extent to which originals and copies are substitutes for consumers, and it shows how some previous analyses are special cases of this general model. The model is then applied to the problem of determining the royalties to be charged for making copies. The analysis in this report should be of interest to economists who study the market for intellectual property, to producers and users of copyrighted material, to those involved in collecting royalties for copying, to copyright attorneys, and to government officials responsible for establishing policies for intellectual property.

SUMMARY

Many owners of intellectual property—including producers of books, journals, computer software, and audio and visual materials—recently have advanced claims of substantial economic losses as a result of unauthorized copying made possible by new technological developments. As a result, legislation has been adopted in a number of countries that provides for compensatory levies under copyright law. Under such arrangements, copyright owners are given the right to demand compensation for the reproductions made of their works from manufacturers of recording equipment or recording media. However, most of these claims alleging harm are based on inadequate data or erroneous assumptions. One of the basic methodological shortcomings of studies of the extent of harm is their failure to compare the behavior of consumers and producers before and after copying is introduced and, in particular, to describe the likely effect of copying on the prices charged for originals.

Several theoretical papers have attempted to analyze the effect of private copying on producer and consumer welfare. These have varied widely in their conclusions, primarily because of the differences in the assumptions made by the authors. One critical assumption is the extent to which sellers of originals can appropriate the value placed on them by all users, including those who make copies. The models fall into two broad categories: those adopting the "indirect appropriability" assumption, in which the demand for originals is assumed to reflect their value both to direct purchasers and to copiers, and those adopting the "direct appropriability" assumption, in which copiers pay only copying costs and do not share in the cost of purchasing originals.

In this report, we present an integrated model that allows us to treat direct and indirect appropriability as outcomes arising from particular assumptions regarding the marginal cost of copying. We show that direct appropriability occurs when the marginal cost of copying is constant and that indirect appropriability occurs when the marginal cost of copying is rising.

The analysis makes clear that the effects of private copying on producer and consumer welfare are difficult to predict. They depend strongly on the assumptions made about the substitutability between originals and copies and on the costs of producing originals and copies.

We examine three cases. In Case I, we assume that the marginal cost of copying is constant and that the value placed on a copy is a

constant proportion of the value of an original for all consumers. In this case, consumers are willing to pay no more for an original than the difference between the value of an original and a copy, plus the copying costs. The result is to reduce the demand for originals, and, therefore, producers are made worse off. Here, consumers gain, either because the price they pay for originals is reduced, or because they are new purchasers (of copies).

In Cases II and III, we assume that the marginal cost of copying increases with the number of copies made from an original. Here the outcome has the characteristics of private goods clubs in which consumers combine to share the cost of originals. If originals and copies are perfect substitutes (Case II), the cost of a "use," either of the original or the copies made from it, is the same to all club members. Where there is imperfect substitutability (Case III), however, there will be identifiable club organizers who will purchase and use originals and distribute copies to all other members.

In these two cases, the assumption of rising marginal cost leads to indirect appropriability, and the prices of originals rise to reflect the fact that they are shared. Here, the effects of introducing copying on producer and consumer welfare depend on the relative costs of club formation and producing originals. If cheaper copies can be substituted for more expensive originals, both producers and consumers are better off. If both are relatively cheap to produce, then, in general, consumers gain and producers lose.

The results underline the need for a careful evaluation of the claims made by producers alleging extensive harm, and show that this harm must be balanced against gains to consumers. They also show how difficult it is to define or measure harm without specifying a complete model of the copying process. Producers have alleged that harm occurs even if their profits are unaffected by copying, because profits are lower than they would have been had the producers been able to exploit the market for copies by charging a copying royalty. We examine this issue by comparing producer profits after copying is introduced, both when a royalty is levied and when copying is unrestricted, with profits in the absence of copying. The results vary considerably depending on whether there is direct or indirect appropriability and on the degree of substitutability between originals and copies. The imposition of a royalty either permits the producer to prevent copying completely, where originals and copies are perfect substitutes, or allows the producer to appropriate some of the value that users place on copies, when they are imperfect substitutes. Thus, royalties can be used either to prevent profits from being reduced by copying or to increase profits by permitting producers to determine the price of copies.

The analysis in this report makes clear that the effects of private copying differ considerably depending on the assumptions made regarding the substitutability between originals and copies and the relative costs of producing copies and originals. This has important implications for the appropriate public policy to pursue regarding such copying.

ACKNOWLEDGMENTS

We wish to acknowledge comments by Stan Liebowitz on an earlier draft, useful discussions with David Grissmer, and very helpful suggestions by Frank Camm and Steven Salop who reviewed a draft of the final report. Salop was especially helpful in pointing out that a number of apparently disparate models could be unified into a common framework.

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I. INTRODUCTION

There is little doubt that the small-scale decentralized reproduction of intellectual property—private copying—is a widespread practice, but its precise extent and economic effects are the subject of considerable dispute. Although the owners of copyrighted computer programs, printed matter, and audio and video tapes have claimed extensive harm from copying,[1] and have occasionally succeeded in having legislation introduced that would compensate them for this harm,[2] the effect of copying is not well understood and its quantitative impact is poorly measured.

A number of recent papers have provided analyses of the effect of private copying on producer and consumer welfare. Liebowitz (1981, 1985) shows that the effect of copying depends importantly on the relative sizes of the markets for originals and copies, the degree to which originals and copies are substitutes in consumption, the number of copies made from each original, and the costs of operating the markets for copies and originals. He concludes that total welfare, consumer surplus plus producer profits, always increases as a result of copying if there are no costs associated with the functioning of such markets.

Besen (1984, 1986) finds that the introduction of copying increases both consumer welfare and producer profits in the short run if and only if copying is efficient, i.e., if the marginal cost of a copy is less than the marginal cost of an original, *and* if the price of originals can be raised to capture the value of the copies that are made from each original. He also points out that if the introduction of copying causes

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[1]See, for example, Davies (1983, pp. 1–75), Greenspan (1983), Cronin et al. (1983, pp. 69–95), and Fishbein et al. (1982, p. 10, 24).

[2]See Davies (1983, pp. 89–119) for a good discussion of proposed legislation in Europe. See Thoms (1984), Reinbothe (1981), and Lucas (1987) for discussions of existing remuneration schemes. The Home Recording Act of 1982 (Amendment 1333 to S. 1758; H. R. 5705) is an example of legislation introduced in the U.S. Congress. It would compensate copyright holders for private copying out of royalties levied on the sale of audio and video "home recording devices and media."

In a number of well-publicized instances, owners of intellectual property have brought lawsuits against copiers. See, for example, *Addison-Wesley Publishing Co., Inc., et al. v. New York University et al.*, a complaint filed in the U.S. District Court, Southern District of New York, December 14, 1982; "Lotus files infringement suit," *Computerworld*, August 6, 1984, p. 14; and "American Brands Named in Piracy Lawsuit," *PC Week*, January 22, 1985, p. 1, 8. In these cases, however, copying was on such a large scale that detection was possible and copyright infringers could be sued. The analysis in this report is confined to situations in which copying is so decentralized that taking legal action against individual copiers is uneconomic.

producers to reduce their prices to discourage copying; their consumers are made better off and producers worse off.

Novos and Waldman (1984) find that an increase in copyright protection may decrease the social welfare loss associated with the underproduction of goods for which exclusion of nonpayers is difficult. This implies that a decrease in copying may increase total welfare. However, by explicitly recognizing that copying may involve a higher social marginal cost than does the production of originals, Novos and Waldman raise the possibility that an increase in copyright protection may increase social welfare as individuals shift from making copies to purchasing originals.

Johnson (1985), in a related paper, concludes that the long-run effect of unlimited copying on social welfare is ambiguous, depending on the elasticity of supply of intellectual property and on the value that consumers place on product variety. As a result, copying may either reduce or increase welfare. In the short run, however, society may be better off by restricting copying because of its higher social marginal cost.

The differences in the conclusions regarding the effects of private copying on social welfare result from differences in the assumptions employed by these authors. One critical assumption is the extent to which the sellers of originals can appropriate the value placed on them by all users, including those who make copies. The models in the literature fall into two categories: those adopting the "indirect appropriability" assumption (Liebowitz, 1981, 1985; and Besen, 1984, 1986), in which the demand for originals is assumed to reflect the value that is placed on originals both by direct purchasers and by all those who use originals indirectly through copying; and those using the assumption of "direct appropriability," in which the cost of originals is borne entirely by their direct purchasers, whereas copiers pay only the costs of making copies (Novos and Waldman, 1984; Johnson, 1985).

In the present report, we present a general model in which both direct appropriability and indirect appropriability appear as particular outcomes. The model focuses on two aspects of private copying, the extent to which originals and copies are regarded as substitutes by consumers and the "technology" for making copies from originals. We show that direct appropriability occurs when the marginal cost of copying is constant and that indirect appropriability occurs when the marginal cost of copying is rising. The model presented in Besen (1984, 1986) is shown to be a special case of the general model in which the marginal cost of copying is constant over some range and infinite thereafter and in which originals and copies are perfect substitutes. We also show that where originals and copies are perfect substitutes

and the marginal cost of copying is rising, the outcome has the characteristics of private goods "clubs" (see Sorenson et al., 1978). In analyzing the determinants of the size of these clubs, we explore the balance between the decreasing average cost of acquiring an original as club size increases and the associated increase in "congestion costs."

The reader should note the similarity between these models and those that examine the effects of the existence of "second-hand" markets on the monopoly power possessed by sellers of new products. For example, the paper by Swan (1980), which examines the implications of the behavior of aluminum recyclers for Alcoa's optimal pricing behavior, is closely related to our analysis of the effect of the behavior of private copiers on the prices that can be charged for originals by producers of intellectual property. Like the analysis in Swan, we find that under certain circumstances copying may produce a social loss if copies replace the production of less expensive originals but that there may be offsetting gains as "recycling" drives the price of intellectual property closer to its social cost.

We also consider the effects of imposing royalties on copying media in both the direct and indirect appropriability models. Because our analysis is limited to the short run, we examine the optimal royalty only from the point of view of producers of intellectual property, although we point out some of the complex issues involved in adopting a longer-run perspective.

Conclusions are presented in the final section.

II. COPYING TECHNOLOGY AND SUBSTITUTABILITY

The models developed in this report focus on two characteristics of private copying. The first concerns the "technology" used to produce copies. In particular, we compare the effects of assuming that the marginal cost of copying is constant with those of assuming that marginal cost rises as the number of copies made from the same original increases. Whether copiers share the costs of originals is shown to depend critically on the assumption made about the cost function for making copies. In other words, the technology determines whether there is indirect appropriability—so that producers can indirectly capture some of the value that copiers place on access to originals.

The second characteristic is the extent to which users regard copies as substitutes for originals. The extent to which originals and copies are regarded as substitutes will depend on such factors as the technical quality of reproduction, the timeliness of the availability of copies, and the importance of complementary goods. Photocopies of journal articles are generally of high technical quality and do not require complementary goods so that they will be close substitutes for originals. Copies of computer software are good substitutes except where instruction manuals are important or where the need to defeat copy protection schemes degrades technical quality. Audio and video tapes generally are good substitutes for originals, and developments such as the digital audio tape recorder are likely to make reproductions even better substitutes. This is important because the extent of substitutability is one of the determinants of the identities of purchasers of originals and of the manner in which the costs of originals are shared between their purchasers and those who copy, if there is indirect appropriability.

We develop three variants of the basic model, each of which is defined by a characterization of copying technology and substitutability.

In Case I, the marginal cost of copying is constant but greater than the marginal cost of producing originals. Copies and originals are assumed to be imperfect substitutes, with the value of copies being the same proportion of the value of originals for all consumers.[1] In this case, the introduction of copying is shown to lower the price of

[1]For reasons discussed below, we do not consider the case in which the marginal cost of copying is constant and originals and copies are perfect substitutes.

originals, but the number of originals sold may either remain constant or decline. Producer profits always fall when copying is introduced, but consumer surplus and social welfare rise if the number of originals remains unchanged. However, if the number of originals declines, the effect on total welfare is ambiguous. An important result is that copiers pay only the cost of copying and do not share the cost of originals, that is, the price of a copy is equal to its marginal cost. Thus, this case is characterized by direct appropriability, i.e., only the value placed on originals by their direct purchasers can be captured by producers.

In Case II, originals and copies are perfect substitutes but the marginal cost of copying is increasing. Here, copying generally leads to fewer originals being sold and to an increase in the price of originals. Unlike the previous case, however, the price paid for an original exceeds the value to its purchaser, i.e., there is indirect appropriability. Even where copying raises the price of an original, however, the result may be to reduce producer profits and consumer surplus may decline as well.

In Case III, originals and copies are imperfect substitutes and the marginal cost of copying is increasing. The results here are similar to those in the previous case except that the identities of the users of originals are known. Originals are purchased, and used, by those consumers who place the highest value on originals relative to copies and who, under the assumptions made here, are the consumers who place the highest value on originals.

III. DIRECT APPROPRIABILITY

This section analyzes direct appropriability in which copiers pay only copying costs and do not share the cost of originals with their purchasers.[1] If the price of an original is greater than the cost of making a copy, the model must also explain why some users purchase originals.

We assume that consumers place a lower value on copies than on originals.[2] Unlike Novos and Waldman, however, we allow consumers to differ in their valuations of originals. And, unlike Johnson, we make a specific assumption about the relationship between the value that consumers place on originals and the value they place on copies (or, equivalently, the perceived cost of copying).

ASSUMPTIONS

We make the following assumptions:

1. The demand for a given intellectual property is linear and downward sloping, the latter reflecting the fact that products of different producers are imperfect substitutes;
2. Consumers regard originals and copies as imperfect substitutes;
3. Each consumer buys at most either one original or one copy;
4. The marginal cost of copies is constant and copies can be made only from originals;
5. Producers are unable to prevent copying, either because they cannot detect copying or because copying is considered to be "fair use" and thus is not a copyright infringement;
6. The marginal cost of originals is constant;
7. Producers attempt to maximize profits.[3]

[1]This is an assumption made in Novos and Waldman (1984) and Johnson (1985) but is an outcome of the models presented here.

[2]This latter assumption is equivalent to assuming that copying costs differ among consumers (Novos and Waldman, 1984, and Johnson, 1985). We prefer to assume that the cost of copying is the same for all consumers and to introduce differences in the valuation of originals and copies through variations in demand.

[3]We do not examine the case in which the marginal cost of copies is constant and originals and copies are perfect substitutes, since this combination of assumptions implies that the producer will wish to sell only a single original at the price that captures the profits earned by the seller of copies made from that original. Because an outcome with only a single source of copies does not involve the small-scale reproduction of intellectual property that is the subject of the present report, we do not analyze it here.

CASE I: ORIGINALS AND COPIES ARE IMPERFECT SUBSTITUTES

Without copying the demand for originals is $P = a - bQ$. Under the assumption of profit maximization, the equilibrium price is $P^* = (a + c)/2$ and the equilibrium quantity is $Q^* = (a - c)/2b$, where c is the constant marginal cost of originals. Total producer profits are given by $(a - c)^2/4b$ and total consumer surplus by $(a - c)^2/8b$.

Because the marginal cost of copies is constant, purchasers of originals would, in competing to sell copies, drive the price of copies to r,[4] their marginal cost. Because copies will sell at their marginal cost, the sale of copies will generate no "surplus" for the purchasers of originals. These purchasers will, therefore, offer for originals no more than the value they place on their use.

To be able to make specific inferences regarding the effects of copying in this model, we assume that the value placed on a copy by any consumer x, $V_c(x)$, is a proportion of the value he places on an original, $V_o(x)$, and that the proportion, α, is the same for all consumers, i.e.,

$$V_c(x) = \alpha\, V_o(x) \qquad 0 < \alpha < 1\,.$$

As a result of the existence of copying, the willingness to pay for originals is reduced, so that a consumer will purchase an original if and only if

$$(V_o - V_c) \geq P_o - r\,,$$

where r is the constant marginal cost (hence the price) of a copy. That is, an original is purchased only when the difference between the value placed on an original and that placed on a copy is greater than or equal to the difference between the price of an original (P_o) and the price of a copy (r).

The demand curve for originals is now

$$P_o = (V_o - V_c) + r = (a - bQ) - (\alpha a - \alpha bQ) + r$$

$$= a(1 - \alpha) - b(1 - \alpha)Q_o + r\,.$$

This implies, as one would expect, that the higher the cost of a copy,

[4]The idea that copies are sold may be metaphorical. Copiers will attempt to copy those originals whose owners demand the least in return. With constant marginal cost, this "price" will be zero if copiers make their own copies and r if they are provided by the purchasers of originals.

the higher is the willingness to pay for an original; in addition, holding r constant, the lower is α (which measures the degree of substitutability between originals and copies), the higher is P_o. In other words, if copies are regarded as poor substitutes for originals, the willingness to pay for originals is correspondingly increased.

This new demand for originals is depicted in Fig. 1 as D_o' and is the kinked curve ABC. The point B occurs where the difference between V_o and V_c exactly equals the difference between P_o and r; indeed, $P_c = r$ and the consumer at this point is indifferent between purchasing an original or a copy. To the right of B, $P_c < r$ and no copies are bought. The lower portion of the demand curve (D_o') then follows the previous demand curve for originals.

The producer now maximizes profits with respect to the new demand for originals by setting the new marginal revenue, MR_o', equal to the marginal cost of originals, c.[5] This results in a new equilibrium

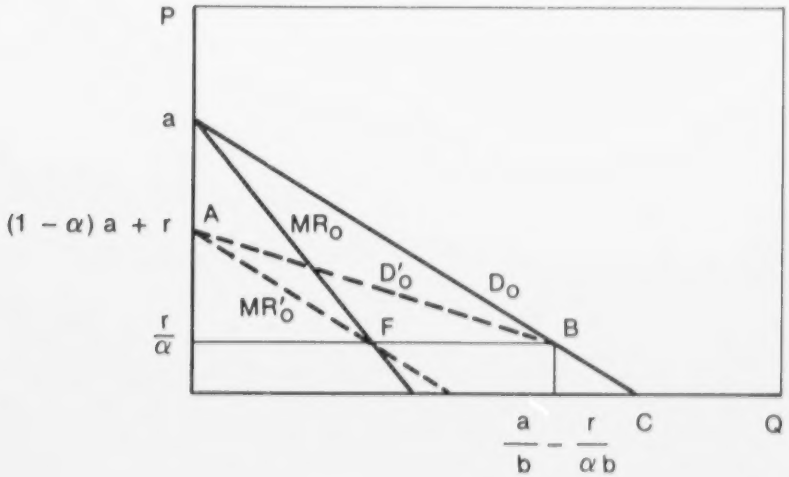

Fig. 1—Demand curve for originals (D_O') when originals and copies are imperfect substitutes

[5]To avoid the durable goods monopoly problem analyzed in detail in Bulow (1982), we assume that the producer of originals cannot change the price he charges after some orig-

price, P^{**}, that is lower than the old price, P^{*}. If marginal cost intersects marginal revenue at or above F, profits *must* decline because the new demand curve is everywhere contained within the old one.[6] The new equilibrium quantity Q^{**} can be lower than or equal to Q^{*}, depending on where the marginal cost of originals, c, intersects the new marginal revenue curve (MR_o) relative to MR_o'.[7] The effect on net welfare in this case depends on whether $Q^{**} \leq Q^{*}$. The possible outcomes are presented in Figs. 2 and 3.

Assume that $Q^{**} = Q^{*}$, as shown in Fig. 2. Then all consumers gain. Previous buyers of originals receive a transfer of producer

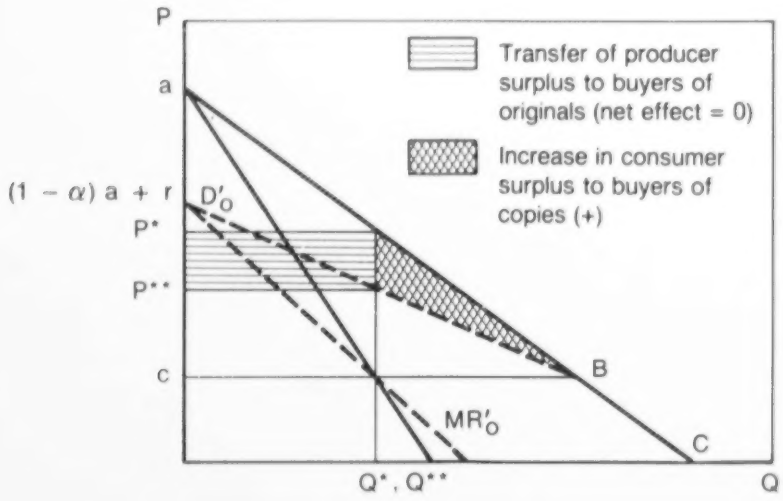

Fig. 2—New equilibrium quantity Q** equal to previous equilibrium quantity Q*

inals have been purchased. A possible rationale for this assumption is that producers who maintain a reputation for not reducing prices can earn higher profits on all of their products.

[6]Note that, unlike Besen (1984, 1986), this result does not depend on the relative values of c and r.

[7]The equilibrium quantity cannot increase because if marginal cost intersects revenue below F the equilibrium does not change.

surplus; new copiers from Q^{**} to Q_c all experience an increase in welfare. Thus, the net effect is to increase total social welfare.

When $Q^{**} < Q^{*}$, however, the analysis is less straightforward. Figure 3 shows the relative changes in producer and consumer welfare. Since buyers of originals to the left of Q^{**} receive a gain equal to the loss to producers, we can ignore this area for purposes of determining the net welfare effect of copying. The producer, in addition, loses an area equal to *WRSU*. Copiers (from Q^{**} to Q_c) gain an area equal to (*MWU* + *WNTU* + *UTV*). Of this, both *MWU* and *WNTU* are merely transfers: The first accrues to previous buyers of originals and now accrues to the same consumers as copiers and *WNTU* is a transfer from the producer to these copiers as well. Thus, the total effect on welfare depends on the relative magnitude of *NRST* (the "uncompensated" loss to the producer) and UTV (the gain to new copiers). Thus, copying can either increase or reduce total welfare.

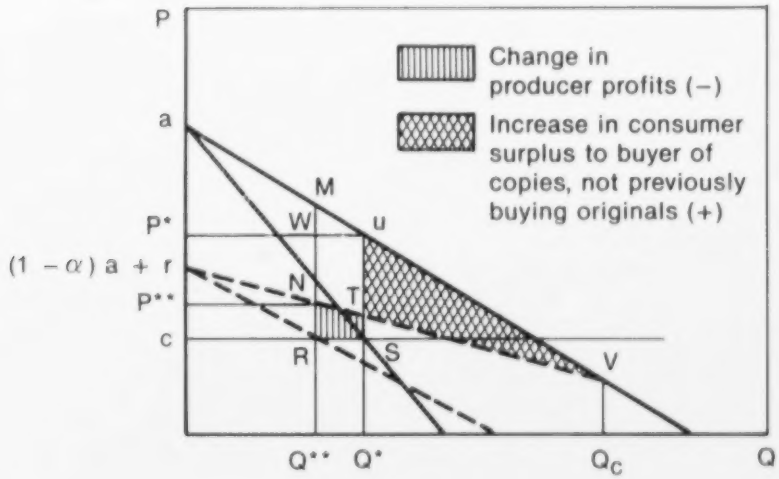

Fig. 3—New equilibrium quantity Q** lower than previous equilibrium quantity Q*

IV. INDIRECT APPROPRIABILITY

To this point, we have assumed that the marginal cost of a copy is constant and we have shown that, as a result, purchasers of copies do not contribute to the price of originals. In this "direct appropriability" model, the value placed on an original by its purchaser must at least equal its price. This section discusses circumstances when this condition does not hold and where the price of an original rises to reflect the fact that it is shared among users.

This "indirect appropriability" result is shown to occur when the marginal cost of copying rises with the number of copies (in contrast to the constant marginal cost assumption of Sec. III). This result has much in common with the analysis of private goods clubs analyzed by Sorenson et al. (1978). One can visualize groups of consumers forming clubs, to buy, and share the costs of, originals from which copies can be made. The incentive for club formation lies in the decreasing cost function associated with a "use." Viewed in this manner, Besen (1984, 1986), who assumed that a fixed number of copies is made from each original, analyzes a special case of the club model where the copying cost function is such that only one optimal size club is possible.

We assume that there are increasing marginal costs of "copying" and that these costs include both reproduction costs and transaction costs that increase with club size. Such costs are given and identical over clubs. We also assume that there are no barriers to the formation of clubs, that copies can be made only from originals,[1] and that all members of a club consume one "use," a copy, with the organizer of the club also consuming one "use," the original.

We discuss two variants of this model: In Case II, originals and copies are regarded as perfect substitutes and in Case III they are imperfect substitutes. Members differ in their valuation of originals and copies as in the previous analysis.

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[1]If copies can be made from copies and the marginal cost of copying is an increasing function of the number of copies made from an original or copy, the price of a copy would be the marginal cost of the first copy made from each original or copy, so that the analysis of Sec. III would apply.

CASE II: ORIGINALS AND COPIES ARE PERFECT SUBSTITUTES

If there is perfect substitutability between originals and copies, for any price of an original the optimal club size is reached where the average cost of club membership is at a minimum. This minimum occurs where the increase in the average variable cost due to an additional member is just balanced by the associated decrease in the average (fixed) cost of an original. All clubs have the same optimal size. As the price of an original increases, the optimal club size also increases because the average fixed cost curve shifts to the right whereas the average variable cost curve remains unchanged.

Because there are no entry barriers, and because the optimal size is identical for all clubs, competition will result in the price of a "use," i.e., a membership, being equal to the minimum average cost. This, in turn, will be equal to the marginal cost of a copy. Because the marginal cost of copying is increasing, the revenues collected from members who use copies will exceed the total cost of making copies. The amount the organizer of a club is willing to pay for an original is equal to this surplus from "selling" copies plus the market price of a "use." Because the demand for originals by clubs reflects not only the value of the use of the original but also this surplus, this is a model of indirect appropriability.[2] Since originals and copies are perfect substitutes, the price of a use must be the same whether it involves an original or a copy.

Assume, for example, that the average cost curve for a club is

$$AC = d(n - 1) + \frac{P_o}{n} ,$$

where n is total club membership, including the organizer, $d(n - 1)$ is the average variable cost of forming a club and making copies, and P_o is the price of an original. Note that this implies that the marginal cost of a club is $d(2n - 1)$, which increases with club size.

Minimizing AC,

$$n^* = \begin{cases} (P_o / d) & \text{for } P_o > d \\ 1 & \text{for } P_o \leq d . \end{cases}$$

[2]Note that, contrary to the claim in Novos and Waldman (1987), indirect appropriability does not require that sellers of copies have market power.

To determine total demand for "uses,"

$$P_{use} = AC^* = dn^* + \frac{P_o}{n^*} = 2(dP_o) .$$

To determine the demand for originals,

$$Q_o = \frac{Q_{use}}{n^*} = \frac{[a - 2(dP_o)] / b}{(P_o / d)} = \frac{a}{b}\left[\frac{d}{P_o}\right] - \frac{2d}{b} ,$$

or,

$$P_o = \left[\frac{a}{bQ_o + 2d}\right]^2 d .$$

The above expression traces out a nonlinear curve. The producer of originals maximizes his profit with respect to this demand curve by setting $MR_o = c$.

It is difficult to determine analytically the effect of copying on the new equilibrium price and quantity. As a result, we have carried out a series of simulations allowing both the slope of the average variable cost of a club, d, and the marginal cost of producing originals, c, to vary.

Tables 1 and 2 summarize the results of these simulations. The demand curve for originals in the absence of copying is assumed to be:

$$P = 25 - Q .$$

We let d take on values from 0.5 to 4. For each value of d, we allow the marginal cost of producing an original to take on values between 1 and 17. Because the object of this exercise is to examine the effects of copying on both producer and consumer welfare, we calculate the profit before and after copying (π_0, π_1) and the price previously paid for an original and the cost of a "use" faced by the consumer once clubs and copying are established (P_0, P_1).

Table 1 relates the ratio of producer profits after the introduction of copying to producer profits before copying, π_1 / π_0, to the marginal cost of producing originals, c, and the slope of the average variable cost of forming clubs, d. In the first four rows, the ratio rises monotonically, indicating that the higher is the marginal cost of originals, the larger are producer profits after the introduction of copying. This mirrors the results in Besen (1984, 1986), in which the substitution of low-cost private copying for the production of costly originals raises producer

Table 1

A COMPARISON OF PRODUCER WELFARE BEFORE AND AFTER COPYING: CASE II

Slope of Average Variable Cost of Clubs = d	c = Marginal Cost of Producing Original								
	1	3	5	7	9	11	13	15	17
0.5	0.53[a]	0.62	0.73	0.88	1.09	1.30	1.86	2.61	3.99
1	0.53	0.60	0.69	0.81	0.98	1.23	1.60	2.21	3.30
2	0.52	0.56	0.62	0.70	0.81	0.97	1.21	1.60	2.28
3	0.50	0.52	0.55	0.60	0.66	0.76	0.91	1.14	1.56
4	1.00	1.00	1.00	1.00	0.55	0.60	0.68	0.80	1.02

[a]This ratio compares the producer's profits after copying (π_1) to profits before copying was introduced (π_0), π_1 / π_0.

Table 2

A COMPARISON OF CONSUMER WELFARE BEFORE AND AFTER COPYING: CASE II

Slope of Average Variable Cost of Clubs = d	c = Marginal Cost of Producing Originals								
	1	3	5	7	9	11	13	15	17
0.5	0.93[a]	0.92	0.88	0.84	0.81	0.77	0.74	0.72	0.69
1	0.98	0.95	0.92	0.89	0.86	0.83	0.80	0.78	0.76
2	1.01	1.00	0.98	0.96	0.94	0.92	0.89	0.87	0.85
3	1.02	1.04	1.04	1.03	1.01	0.99	0.96	0.94	0.92
4	1.00	1.00	1.00	1.00	1.06	1.04	1.02	1.00	0.98

[a]This ratio compares the "cost" of a use to consumers after copying (P_1) to the price previously paid for originals (P_0), P_1 / P_0.

profits.[3] However, profits rise with the introduction of copying only after some critical value of c is reached, with the critical value being higher the larger is d.

[3]Note that these results are intermediate between those in Besen (1984, 1986) and those in Case I. In the former, the marginal cost of clubs is implicitly horizontal until the optimal club size is reached and vertical thereafter. The eventually rising marginal cost permits indirect appropriability and, if the marginal cost of copying is low, producers are made better off. In Case I, where marginal cost is constant throughout, and thus there is only direct appropriability, a low marginal cost of copying reduces profits by limiting the price that can be charged for originals. Here, a low value of d benefits producers by permitting the substitution of low-cost copies for more expensive originals but it also harms them because it implies that the extent of indirect appropriability will be small.

The results in the fifth row, $d = 4$, are somewhat different in that for low values of c it does not pay to copy at all, so that profits are unaffected by the introduction of copying. However, once a critical value of c is reached, copying occurs and producer profits decline. As c continues to rise, profits increase and, beyond a second critical point, they are larger than before copying was introduced.

A similar story can be told by looking at the columns in Table 1. In the first four columns, for any value of c, profits decline as d rises, indicating that more and more expensive copying is replacing the production of originals. However, once a critical value of d is reached, it becomes uneconomic to copy, so that profits return to their original value. In all of these cases, profits are below their value before copying because c is low.

In the last five columns, the introduction of copying raises profits for combinations of low values of d and high values of c. This reflects the substitution of inexpensive copies for costly originals. However, as d rises, profits decline and eventually fall below their value before copying. Although not shown in the table, once a second critical value of d is reached, copying becomes uneconomic and profits remain at their original value.

Table 2 presents the ratio of the price of a "use" after and before the introduction of copying.[4] In the first four rows, the price of a use falls monotonically as the cost of producing an original rises, indicating the substitution of inexpensive copies for costly originals. For low values of c in the third and fourth rows, however, the price of a use is increased by the introduction of copying. In the fifth row, representing a high cost of forming clubs, no copying occurs at low values of c, so that there is no change in the price of originals. Beyond some point, however, copying occurs and initially raises the price of a use. As c continues to rise, however, the price of a use declines and eventually falls below its initial value.

If we examine the columns in Table 2, similar results are obtained. As d rises for a given marginal cost of originals, the price of a use increases and eventually exceeds the initial price of originals. The critical value of d at which this occurs is higher the higher is c. However, when d reaches a second critical value, it no longer pays to copy and the price of a use returns to the initial price of originals.

Finally, it is useful to compare the results in Tables 1 and 2. Producer profits are improved by copying whenever the ratio in Table 1 exceeds 1, whereas consumers are better off whenever the ratio in Table 2 is less than 1. Note that for low values of d relative to c, e.g.,

[4]The latter is, of course, the price initially charged for an original.

$c = 17$, $d = 1$, both consumers and producers benefit from the introduction of copying. By contrast, for high values of d relative to c, e.g., $c = 1$, $d = 3$, both are made worse off. However, copying does not always have the same effect on consumers as on producers. For example, when $c = 7$ and $d = 1$, producers are worse off whereas consumers are better off.[5]

We can characterize our results in this club model as follows:

1. If the marginal cost of producing originals is high relative to the cost of forming clubs, copying increases both producer and consumer welfare, as copies replace more costly originals.
2. If the relative cost of club formation is high and clubs are formed, in general both producers and consumers lose.
3. If both copies and originals can be produced efficiently (both d and c are low), in general, producers lose and consumers gain from the introduction of copying. The effect on total welfare is ambiguous.

CASE III: ORIGINALS AND COPIES ARE IMPERFECT SUBSTITUTES

This case is somewhat more complicated to analyze than the previous one because there are now two factors affecting the demand curve: the formation of clubs and indirect appropriability, and the differential value placed on copies and originals. To keep the analysis tractable, we assume as we did previously that $V_c = \alpha V_o$, $0 < \alpha < 1$, i.e., the value of a copy is a constant proportion of the value of an original. As in Case II, we assume increasing costs of forming clubs. The organizer of the club will purchase and use the original and will sell $(n^* - 1)$ copies made from it.

In the previous case, because copies and originals were perfect substitutes, no organizer of a club would be willing to pay to use an original more than $AC^* = P_c$, the price charged for a copy to each club member.[6] In this analysis, because copies are valued less than originals, there will be a difference in the prices of using originals and copies; this amount is equal to the difference between the surplus generated by the original and that generated by the copy. In other words, the organizer of the club would be the consumer for whom

[5]As in Besen (1984, 1986), a low cost of copying limits the ability of producers to raise the price of originals.

[6]The price offered for an original was, of course, higher than P_c because of the surplus generated over copying costs by the increasing marginal cost of club formation.

$[(V_o - P_o) - (V_c - P_c)]$ is a maximum. The total amount he would be willing to pay for the original is, however, greater than this (by the same reasoning as in Case II), by an amount equal to the producer surplus associated with club formation. For the marginal organizer of clubs and, therefore, the marginal purchaser of originals,

$$(V_o - P_o) - (V_c - P_c) + [P_c(n^* - 1) - TC] = 0 ,$$

where $P_c(n^* - 1)$ is the revenue he collects from other club members and TC is the total cost of forming a club. Then,

$$P_o = V_o(1 - \alpha) + P_c + [P_c(n^* - 1) - TC] .$$

A typical case is illustrated in Fig. 4. The lower graph shows the costs of copying and the determination of optimal club size, n^*. The organizer of the club collects $[P_c(n^* - 1) - TC]$ where TC is the area under the marginal cost curve. The value he places on an original is shown in the top graph as V_o. The surplus, however, allows him to offer P_o for the original, an instance of indirect appropriability. This in turn implies that the demand for originals shifts upward. The producer of originals maximizes his profits with respect to this demand curve and the interdependence between the two markets insures equilibrium in the copying market as well.

In this case, there are identifiable club organizers. They are the consumers for whom the value of originals relative to copies is greatest. Under the assumptions of the model, these are the consumers who place the highest value on originals.

SUMMARY

The above analysis of the direct and indirect appropriability models makes clear that the effects of private copying on producer and consumer welfare are difficult to predict. They depend strongly on the assumptions made about the substitutability between originals and copies and on the relative costs of producing originals and copies.

If the marginal cost of copying is constant, and copying is introduced, producer profits must decline. This occurs because the producer must lower the price of originals to compete successfully with copies. If copies are valued less than originals, a downward sloping demand for originals will still exist but it will be lower than previously because of the existence of copies. Consumers generally gain in this case, either because the price of originals is reduced by copying or because they are new purchasers (of copies).

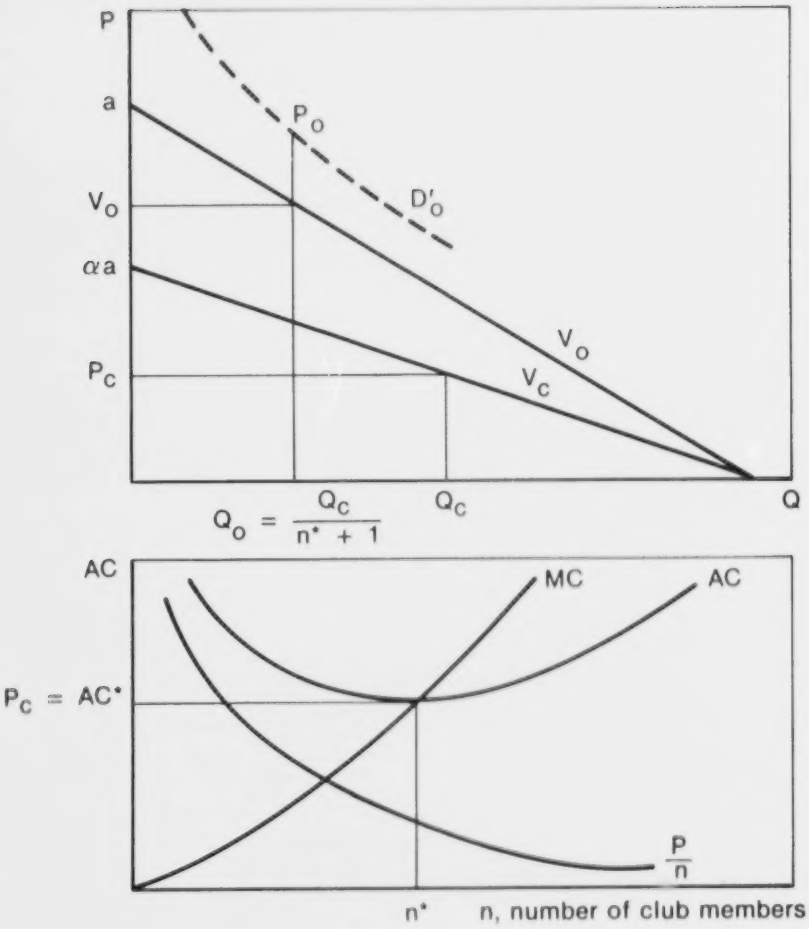

Fig. 4—Originals and copies are imperfect substitutes; increasing marginal cost of copying

The situation is somewhat different when the marginal cost of copying increases with the number of copies. Here, the analysis is analogous to models in which consumers form clubs to share the cost of originals. The assumption of rising marginal cost leads to indirect appropriability, where the price of originals rises to reflect the fact that it is shared among users. Some illustrative simulations showed that, in this model, the effects on producer and consumer welfare depend on the relative costs of forming clubs and producing originals. If cheaper copies can be substituted for more expensive originals, both producers and consumers are better off. If both are relatively inexpensive to produce, then, in general, producers lose and consumers gain. These qualitative results do not depend on the substitutability between originals and copies.

These results highlight the fact that general claims of extensive harm by producers of intellectual property need to be balanced against possible gains to consumers, even in an analysis limited to the short run. Moreover, they show how difficult it is to measure harm without specifying a complete model of the copying process. The next section examines the determination of royalties designed to permit producers to profit from the existence of copying.

V. THE DETERMINATION OF OPTIMAL COPYING ROYALTIES

Some countries have adopted, and others are considering, the imposition of royalties on copying. These royalties will generate revenues to compensate producers of intellectual property for the effects of private copying. Often, these arrangements involve the imposition of a fee on either the recording medium or the recording machinery. The fees are established either by legislation, by producers, or by a government agency.

Such arrangements are becoming more common. For example, in the United States, those who photocopy printed matter beyond the "fair use" exemption are expected to make payments to publishers through the Copyright Clearance Center (see Spilhaus, 1978). This involves an implicit license to copy. However, under this arrangement, publishers may be required to bring suit against those who copy without obtaining a license. By contrast, where the fee is placed on the recording medium, copying need not be monitored. In the Federal Republic of Germany, for example, there is a levy on manufacturers and importers of recording equipment. The remuneration consists of an equitable share of the proceeds resulting from the sale of the equipment, but the total amount is limited to 5 percent of the proceeds of the sale (Ulmer, 1983). In both Austria and Germany, authors of audiovisual works have similar rights against manufacturers of blank tapes, with the amount of the royalty being established by law (UNESCO and WIPO, 1984).

What has given rise to these royalty schemes are claims by producers alleging extensive harm because of lost sales as a result of widespread private copying. The question of what constitutes harm is thus of considerable importance. Two possible definitions can be suggested. Under the first, harm is measured by the reduction in producer profits below their level before a new unauthorized use. Under this definition, harm does not occur if the unauthorized use leaves profits from all previous uses unaffected.

Under a broader definition, harm occurs if the new use reduces profits below the level they would have reached had the producer been able to exploit the market served without authorization. Thus, even where producer profits do not decline, unrestricted copying may still be

thought of as causing harm. This is because, if the law permits royalties to be imposed, producers may be able to benefit from copying.[1] These charges would, of course, be less than the price that is charged for originals.[2] Alternatively, producers could benefit if a royalty were imposed on the copying medium with the proceeds being paid to producers.

The models presented here permit the analysis of the determination of an "optimal" royalty by producers seeking to maximize profits, for the three cases presented above. We are aware of the anomaly in discussing "optimal" royalties when our analysis has focused strictly on the short run. However, the analysis is useful in understanding the behavior of producers if they are permitted to restrict copying. The discussion below assumes that producers can impose a fee for each copy and that "licenses" to copy can be produced without cost,[3] i.e., there are no information or policing costs.

DIRECT APPROPRIABILITY MODEL

Case I: Originals and Copies Are Imperfect Substitutes

Given our former assumption that the value of a copy is a constant proportion of the value of an original,

$$V_o = \alpha V_c ,$$

the demand curve for originals after the introduction of copying is

$$P_o = a(1 - \alpha) - b(1 - \alpha)Q_o + r .$$

If a fee, P_L, is charged for a license to copy, this becomes

$$P_o = a(1 - \alpha) - b(1 - \alpha)Q_o + r + P_L .$$

For any P_o, P_L combination, there will be a consumer who is indifferent between originals and copies. For this consumer,

$$V_o - P_o = V_c - P_L - r$$

[1]See Besen (1987) for an analysis of this issue.

[2]This is both because copies may be imperfect substitutes for originals and because there are costs associated with making copies.

[3]This assumption is not strictly necessary for the analysis to hold. It is adopted for ease of exposition.

or

$$V_o = \frac{P_o - P_L - r}{1 - \alpha} .$$

By substitution, we find that this consumer (and, therefore, the quantity of originals purchased) is

$$Q_o = \frac{a}{b} - \left[\frac{P_o - P_L - r}{1 - \alpha}\right] .$$

Those to the right of this consumer purchase only copies since, by definition, for them, $V_o - P_o < V_c - P_L - r$. To find the total quantity of originals plus copies purchased, we find the consumer for whom $V_c = P_L + r$. This is

$$Q_{o+c} = \frac{a\alpha - P_L - r}{\alpha b} = \frac{a}{b} - \left[\frac{P_L + r}{\alpha b}\right] .$$

Thus, the number of copies purchased is $Q_{o+c} - Q_o$ or

$$Q_c = \frac{\alpha P_o - P_L - r}{\alpha b(1 - \alpha)} .$$

From this, we can derive the demand for licenses (which is, of course, identical to the demand for copies)

$$P_L = \alpha P_o - r - \alpha b(1 - \alpha)Q_L$$

where $Q_L = Q_c$.

The producer now maximizes his combined profits in the two markets, taking into account the fact that originals and copies are substitutes, analogous to a multiproduct monopolist. We can write his profit function as

$$\Pi = (P_o - c)Q_o + P_L Q_L .$$

We can rewrite the demand functions as functions of the two quantities Q_o, Q_L. Substituting these into the profit function, we get

$$\Pi = [a - bQ_o - \alpha bQ_L - c]Q_o + [\alpha a - \alpha bQ_o - \alpha bQ_L - r]Q_L .$$

Setting the partial derivatives with respect to Q_o and Q_L to zero and solving for the optimal quantities and prices we obtain

$$Q_o^* = \frac{a}{2b} + \frac{r - c}{2b(1 - \alpha)}$$

$$Q_L^* = \frac{\alpha c - r}{2\alpha b(1 - \alpha)}$$

$$P_o^* = \frac{a + c}{2}$$

$$P_L^* = \frac{\alpha a - r}{2} .$$

The rather surprising results here are that the price of originals does not depend on the cost of copies; the copying royalty is set independently of the price of originals; and the price of originals is unaffected by copying.[4] The two quantities clearly, however, do depend on the costs of both originals and copies.

A typical equilibrium is depicted in Fig. 5. D_o' is the new demand for originals, which is itself a function of P_L^*. The marginal consumer of originals is indifferent between purchasing originals and copies, i.e., $V_o - P_o^* = V_c - r - P_L$. To his left, consumers purchase originals and receive a surplus equal to the area under the demand curve (D_o) and P_o^*. To the right of Q_o^*, up to Q_{o+c}^*, consumers purchase copies; the producer receives P_L from each of them. Beyond Q_{o+c}^*, it can be seen from the V_c curve that consumers value copies less than $r + P_L^*$.

The producer's profits increase as a result of the royalty, although the fee is critically dependent on α, the degree of substitutability between originals and copies, and r, the cost of copying. Two illustrations are given in Table 3. We assume that $a = 25$, $b = 1$, $c = 2$, and $r = 1$. The equilibrium both before and after copying is shown to permit comparison of producer welfare. Notice that once copying is introduced, the producer suffers harm, even by the narrower definition given above, that compared his profits before and after the introduction of copying. Indeed, when originals and copies are good substitutes, $\alpha = 0.8$, the extent of harm is considerable. When a royalty is levied on copiers, however, the producer is better off in both cases with profits that are even larger than in the precopying equilibrium.[5]

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[4]We believe that these are not general results.

[5]If this were not the case, the producer would set the royalty at a level that would discourage copying completely so that profits would be unchanged.

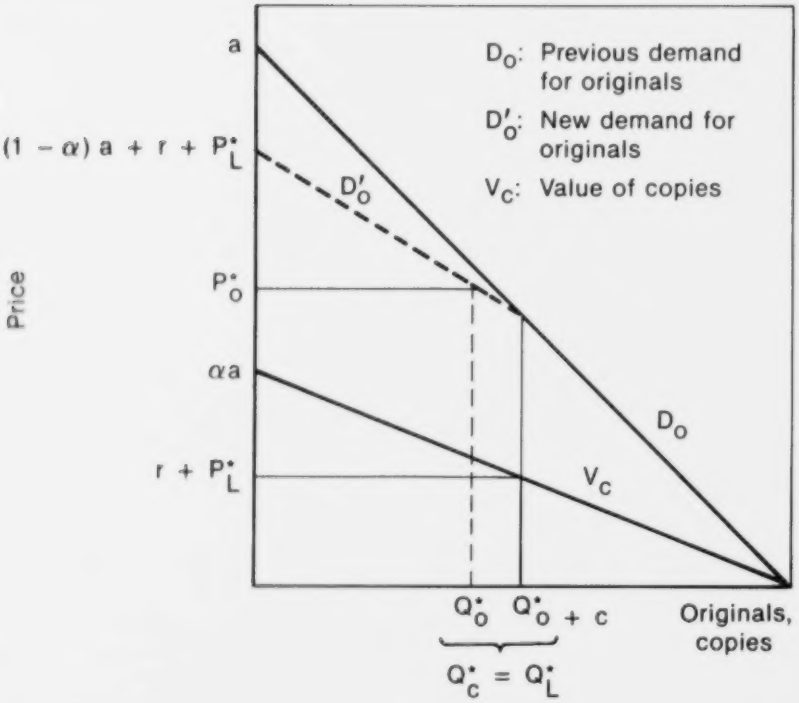

Fig. 5—Equilibrium in the market for originals and copies, with an optimal royalty of P_L

INDIRECT APPROPRIABILITY MODELS

Case II: Originals and Copies Are Perfect Substitutes

Case II relaxes the assumption of constant marginal cost of copying. This allows clubs to be formed and leads to an outcome of indirect appropriability, where the producer is able to capture the value of

Table 3

OPTIMAL ROYALTIES AND PRODUCER PROFITS: CASE I
(In dollars)

		After Copying			
		Originals and Copies are Poor Substitutes: $\alpha = 0.4$		Originals and Copies are Good Substitutes: $\alpha = 0.8$	
Equilibrium	Before Copying	Without Royalty	With Royalty	Without Royalty	With Royalty
P_o	14.50	10.00	14.50	5.00	14.50
Q_o	10.50	10.00	10.00	5.00	5.00
P_L	—	—	4.50	—	9.50
Q_L	—	—	1.25	—	6.88
π^*	110.25	60.00	110.63	5.00	117.81

originals both to purchasers of originals and to those who make copies from them. In this case, the optimal copying royalty is either zero, so that copying is unrestricted, or large enough to deter copying completely. When the introduction of copying raises profits, the best strategy for the producer is to permit copying without restriction. When copying lowers profits, the producer will wish to prevent copying altogether.

The result that the optimal copying royalty is either zero or high enough to prevent copying arises from the assumption that originals and copies are perfect substitutes. The easiest way to understand the result is to think of the producer as engaged in the sale of "uses," either directly through the sale of originals or indirectly through the copies that are made from them. In this case, because originals and copies are perfect substitutes, they will have the same price. But the producer is unconstrained in setting this price, through his control over the price of originals, so that he gains nothing by being able to impose a royalty on copying. By contrast, in Case I, where originals and copies are imperfect substitutes, without a copying royalty the producer can establish only the price of originals, since the price of using a copy is constrained to equal the marginal cost of a copy. A copying royalty permits him to establish the separate prices for using originals and copies that are needed for profit maximization.

Before the introduction of copying, the producer will set the price of originals, and, equivalently, of uses, at the level that maximizes his profits. If there is copying, profits can only increase if the cost of producing uses declines, since the demand for uses is unchanged, although the demand for originals has changed because of indirect appropriability.[6] But if the introduction of copying raises profits, the producer cannot increase his profits further by imposing an additional charge on copying. When copying causes profits to fall, this must mean that the cost of producing a use has increased, so that the profit-maximizing royalty must be high enough to return the supplier to the original equilibrium.

Examples of the two situations are presented in Table 4. We assume that $a = 25$, $b = 1$, and $d = 0.5$. We calculate profits both before and after copying for both low and high c, the marginal cost of producing originals.

Case III: Originals and Copies Are Imperfect Substitutes

The determination of optimal copying royalties in this case is much more difficult to analyze because there is both indirect appropriability and originals and copies are imperfect substitutes. The producer will wish to set two prices, one for using an original and one for using a

Table 4

OPTIMAL ROYALTIES AND PRODUCER PROFITS: CASE II
(In dollars)

	$c = 5.00$		$c = 15.00$	
Equilibrium	Before Copying	After Copying	Before Copying	After Copying
P_0	15.00	87.25	20.00	104.75
Q_0	10.00	0.89	5.00	0.73
π^*	100.00	73.41	25.00	65.27
P_L	—	Large enough to deter copying completely		0

[6]This reduction in the cost of producing uses, which results from the formation of clubs, is most likely to occur when the cost of originals is high. When the cost of originals is low, the formation of clubs is likely to cause an increase in the cost of producing a use.

copy. However, if there is no royalty on copying, the relationship between the two prices will be determined completely by the extent to which originals and copies are substitutes, the marginal cost of originals, and the marginal cost of copies. But the relative prices produced in this manner need not be the prices that maximize profits. As a result, the producer will generally wish to impose a royalty on copying. This is similar to the result in Case I where originals and copies are imperfect substitutes, but different from that in Case II where they are perfect substitutes.

SOME OBSERVATIONS ON THE LONG RUN

Clearly, the optimal policy to pursue in the face of private copying depends on more than the short-run behavior analyzed in this report. If private copying reduces producer profits, the effect may be to reduce the amount of resources devoted to the creation of intellectual property and that decline must be taken into account in any policy analysis. Nonetheless, the results in the present report may still be useful in determining which policy to pursue.

Copyright policy depends on a balancing of two considerations. The larger the range of rights granted to copyright holders (for example, the longer is the period of copyright protection), the larger will be the profits from creating intellectual property and the more such property will be created. At the same time, an expansion in the rights of the creators will reduce the value to consumers of any intellectual property once it has been created. Finding the right copyright policy involves a tradeoff between increasing the incentive to create and increasing the use of that which has already been created.

If one is prepared to assume that the appropriate balance was struck before the introduction of private copying, then the analysis in this report can be used to guide policymaking after its introduction. Where the introduction of copying has the same effect in the short run on both consumers and producers, the needed policy is clear. If copying makes both better off, there is no need to restrict it. If, on the other hand, both are worse off, then copying should be restricted.

More difficult are those cases, like many of those reported here, where the short-run effects move in opposite directions. In many of the variants of the model developed here, the introduction of copying makes producers worse off and consumers better off. If only short-run effects are considered, and if profits and consumer surplus are weighted equally, then determining the appropriate policy would require "only" measuring whether producers lose more than consumers gain from copying.

If, for example, consumers gain more than producers lose, a short-run analysis would suggest that copying should not be restricted. However, this conclusion could be reversed if the effects of the reduction in profits on the incentives to create are considered. Restricting copying would appear to be more appropriate in those cases where the gain to consumers is not much greater than the loss to producers—*a fortiori*, this is so where consumers gain less than producers lose—than it is where the gain to consumers is much greater than the amount that producers lose. This is because in the former the short-run welfare gain is more likely to offset the loss in creative effort that would be caused by the reduction in profits. Needless to say, the appropriate determination will depend on the difficult assessment of the extent to which additional producer profits increase the incentive to create.

VI. CONCLUSIONS

Although private copying of intellectual property is presently widespread, and is likely to become even more so in the future, its effects are poorly understood. This report is an attempt to analyze the economic effects of copying. These effects depend importantly on whether or not one assumes that the demand for the originals from which copies are made reflects the values that users place on these copies. When the demand for originals reflects the demand for copies, i.e., there is indirect appropriability, the interests of producers and consumers of intellectual property are generally congruent. On the other hand, these interests are likely to diverge when it is assumed that there is only direct appropriability, i.e., that the demand for originals reflects only the value placed on them by their direct purchasers. In the latter case, at least some copiers may gain from copying even if producers lose as a result.

In the models presented in this report, direct and indirect appropriability result from the assumptions made about the "technology" of copying. If the marginal cost of copying is constant, the demand for originals is reduced by copying to an extent dependent on the degree of substitutability between originals and copies. This means that producers are always made worse off by the introduction of copying, whereas all consumers, both purchasers of originals and copies, gain.

If the marginal cost of copying increases with the number of copies, then the analysis is similar to that of the economics of clubs, where consumers combine to share the cost of originals. The optimal size of these clubs is determined by both the price of originals and the cost of forming clubs. In turn, the demand for originals reflects the size of the clubs that are formed to share them. As in the case where the size of the sharing group is fixed, consumer and producer welfare generally increase when copying is efficient and decline when it is not. However, when the costs of both originals and copies are low, producers will generally lose and consumers will gain from the introduction of copying.

The question of royalties to compensate producers for the alleged harm from copying is of considerable importance, given the widespread adoption of compensatory schemes in several countries. We show that, when originals and copies are imperfect substitutes, the producer may be made better off by the imposition of a royalty. However, where there is indirect appropriability, the optimal royalty may be zero if

originals and copies are perfect substitutes. We find that where either the cost of copying is low, or originals are expensive to produce, the producer may be better off not imposing a royalty.

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